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(54) Title: METHOD OF UPDATING A CONTROL CHANNEL LIST IN MOBILE COMMUNICATIONS SYSTEM

(57) Abstract: A technique for allowing a mobile radio unit of a mobile radio communications system to find and synchronise to a signal of its radio system. The mobile unit stores a list of frequencies used by the radio system where it can expect to find radio system synchronization signals. To find a signal of the radio system, the mobile unit initially scans all the frequencies in its list to assess the signal level on each frequency, and to assess whether the signal on each frequency has particular characteristics, e.g. the phase shift characteristics, of a signal of the radio system. The probability that the signal has the correct signal characteristics is stored with the signal level and the frequencies in the list are then reordered according to the measured signal levels and the probability that the signals have the required particular signal characteristics, to provide a revised frequency order for the mobile unit to then attempt to synchronise to.

METHOD OF UPDATING A CONTROL CHANNEL LIST IN MOBILE COMMUNICATIONS SYSTEM

5   The present invention relates to mobile radio
communications systems and in particular to a method of
and an apparatus for enabling a mobile radio unit of a
mobile radio communications system to find and acquire a
radio channel for communicating with a base station of
10   the mobile radio communications system.
          As is known in the art, for a mobile radio unit of
a mobile radio communications system to be able to
communicate with the fixed radio network (and thereby
operate in the radio system), the mobile radio unit must
15   be tuned to a radio channel of a base station of the
mobile radio system. This means that whenever a mobile
radio unit first becomes active, or migrates into a new
area, it must, before it can communicate with the radio
system, identify and synchronise to a suitable base
20   station radio channel.
          Similarly, if it is necessary for a mobile radio
unit to be handed over from a first base station to a
second base station during an on-going call, the mobile
radio unit must be able to identify and synchronise to a
25   radio channel of the new base station.
          To minimise any interruption in communication when
a mobile radio unit needs to find the new base station,
it is desirable for the mobile radio unit to be able to
recognise and synchronise to the new base station radio
30   channel as quickly as possible, particularly during a
handover (as handover desirably occurs with the minimum
possible interruption in communication).
          To facilitate the identification of and subsequent
synchronisation to a suitable base radio station
35   channel, mobile radio units will typically, as is known
in the art, store a list of radio frequencies used by
base stations of the radio system, and, when it is

necessary to find a new radio channel, tune in turn to
each frequency in the stored list and attempt to
synchronise on each frequency until a suitable radio
channel is found.

5   The channel synchronisation search typically
comprises the mobile radio unit listening on the
particular frequency for a limited period of time to try
to detect special synchronisation signalling which
should be present on the frequency if it is available

10   and suitable for the mobile radio unit to use. If the
mobile radio unit does not detect the synchronisation
signalling during the waiting time period, the mobile
radio unit will turn to another frequency on its list,
and so on, until it succeeds in synchronising on a

15   frequency with a suitable signal.

          However, in many mobile radio systems, the
synchronisation signals may only be broadcast at
intervals. For example, synchronisation signals are
broadcast at intervals of 235 ms in the GSM (Global

20   System for Mobile communications) system. In the TETRA
(TErrestrial Trunked RAdio) system, synchronisation
signals may only be broadcast at intervals of up to 4
seconds.

          The search waiting time period on each frequency

25   must therefore be at least the expected interval between
synchronisation signals to allow sufficient time for a
synchronisation signal to be received, before trying
another frequency. In practice, the waiting time will
often be longer than a single synchronisation signal

30   interval, as typically, sufficient time to receive two
or three synchronisation signals is allowed on each
frequency in order to, for example, reduce the effects
of fading causing suitable synchronisation signals to be
improperly received.

35   Thus, for example, to identify and synchronise on a
good TETRA signal could take well over 1 minute if the
mobile radio unit has just been switched on in a new

area and it has a list of, for example, sixty possible
frequencies to search. Such delay in channel
acquisition is undesirable, as it increases the
interruption in communications when a new radio channel
5   is required.

It is known therefore to modify the base station
radio channel search process to try to reduce the
possible delay in identifying and synchronising to a new
base station radio channel.

10   For example, in some radio systems, including the
TETRA system, the frequencies used by adjacent base
stations may be broadcast to mobile radio units, so that
the number of frequencies to be searched for a suitable
radio signal when moving to an adjacent area can be

15   reduced. However, even in that case, having to pause on
each possible frequency for several seconds from even a
reduced search list can still mean that it takes up to a
minute to find a strong signal and synchronise to it.

.Another common method of speeding up the scanning

20   of potential frequencies in the frequency list is to
tune to each of the frequencies for a relatively short
period of time to measure the signal level on the
frequency (but not necessarily long enough to receive a
synchronisation signal). The mobile radio unit then

25   records the signal level and moves on to the next
frequency to be inspected. This process is typically
repeated several times, as is known in the art, to build
up a set of spaced signal level measurements for each
frequency, which measurements are then, for example,

30   averaged to give an overall signal level estimate for
the frequency. When the mobile radio unit has been
through its list of candidate frequencies a sufficient
number of times, it ranks them in order of signal level
and, starting with the frequency having the highest

35   measured signal level, returns to the frequencies to
listen for a longer period of time for synchronisation
signals on each frequency in turn until it achieves

synchronisation.

This technique helps to reduce the radio channel acquisition time. However, the Applicants have recognised that it can still have problems. For example, frequencies on which there are strong interfering signals with relatively high signal levels will still tend to be placed at the top of the revised list of frequencies to be examined in detail following the initial faster frequency scan, even if those frequencies could in practice be unusable. Thus a mobile radio unit may still waste time trying to obtain synchronisation on an inappropriate signal before working on down its list to choose a compatible base station radio channel.

According to a first aspect of the present invention, there is provided a method of operating a mobile radio unit of a mobile radio communications system, in which radio system the mobile radio unit stores a list of target frequencies to scan for a suitable frequency for communicating with a base station of the radio system, the method comprising:

the mobile radio unit scanning each frequency in its list, and determining for each frequency the signal level of the signal on that frequency, and assessing for each frequency whether the signal on that frequency has a particular characteristic of the radio system;

the mobile radio unit then determining a revised frequency order on the basis of the determined signal levels and the characteristic assessments for each frequency; and

the mobile radio unit then attempting to synchronise to the frequencies in the revised frequency order in the order of the revised frequency order.

According to a second aspect of the present invention, there is provided a mobile radio unit for use in a mobile radio communications system, in which system plural frequencies are used for radio communications,

the mobile radio unit comprising:

        means for storing a list of frequencies used by the
radio system;

        means for scanning each frequency in the stored
list;

        means for determining for each scanned frequency
the signal level of the signal on that frequency;

        means for assessing for each scanned frequency
whether the signal on that frequency has a particular
characteristic of the radio system;

        means for determining a revised frequency order
based on the determined signal levels of each frequency
and the assessments of whether each frequency has the
particular characteristic of the radio system; and

        means for attempting to synchronise to the
frequencies in the revised frequency order in the order
of the revised frequency order.

        In the present invention, as in the known frequency
searching techniques, an initial scan of the frequency
list stored by the mobile radio unit is carried out, but
as well as determining the signal level of each
frequency during the initial scan, an assessment of
whether the signal on the particular frequency has a
particular characteristic of the radio system is also
made. The signal level and characteristic assessment
results are then used together to derive a revised order
in which to scan the frequencies for synchronisation
signals.

        The Applicants have recognised that many radio
systems will have characteristic properties to their
signals that can be relatively rapidly identified and
will distinguish them from signals of other radio
systems. Thus assessing whether the signal on each
frequency has the relevant particular characteristic
gives an assessment of the likelihood of the signal on
that frequency being from the correct radio system. The
assessment of whether the signal has the relevant

particular characteristic can also give a measure of how 'useful' the signal is likely to be, since, if the signal shows the relevant signal characteristic strongly, that would suggest that the signal is valid
5   and useful.

Thus the assessment of whether the signal has the relevant particular characteristic can be used to place signals more likely to be from the correct radio system and more likely to be useable towards the top of the
10 revised frequency list for the synchronisation scan so as to reduce the possibility of trying to synchronise to an alien or incompatible signal before more suitable signals are considered.

Thus the present invention provides a refined
15 process for selecting those signals (i.e. frequencies) to attempt to synchronise to first, which can be used to improve the order in which the frequencies are scanned for synchronisation to scan what appear to be more suitable signals first and thereby to reduce the
20 possibility of wasting time trying to synchronise on incompatible signals and to improve the speed at which a new suitable frequency (and therefore base station) is acquired.

The initial faster frequency scan can be carried
25 out as desired. For example, the mobile radio unit could pause once on each frequency in its list in turn to carry out the signal assessment. However, the initial scan is preferably carried out by the mobile unit carrying out plural measurements at spaced
30 intervals on each frequency, preferably by returning to each frequency to be scanned at spaced intervals during the initial scan, e.g. such that an assessment is carried out on each frequency in turn and the cycle of measurements over the different frequencies is repeated
35 several (i.e. two or more) times. This method ensures that successively assessed signal samples on the same frequency are relatively well-spaced in time, thereby

providing better averaging of the measurements, and
helping to ensure that not all measurements on a
frequency are made during the same fade (unless the
receiver is stationary).

5   The frequency list to be scanned could be the list
of all frequencies used by the radio system, or it could
be a reduced list, for example of only those frequencies
known to be in use in the particular area, or in
adjacent cells, as is known in the art.

10   The signal level for each frequency can be
estimated as desired and in any suitable manner known in
the art.

           The characteristic of the radio system for which
the signals are assessed can be selected as desired. It
15   should be a characteristic of the system that can be
used to distinguish it from other radio systems. It
should also not take too long to assess and preferably
can be assessed in the same time that it takes to
determine the signal level, i.e. such that the
20   characteristic assessment does not extend the duration
of the initial faster frequency scan. More than one
characteristic can be considered if desired.
Preferably, the characteristic of the signal is
assessed, and the observed signal characteristics are
25   then compared with the expected characteristics for the
radio system, e.g. to see how well they correspond, to
assess whether the signal has the required
characteristic.

           In a particularly preferred embodiment, the signal
30   characteristic assessment comprises assessing whether
the signal has a characteristic of the radio modulation
scheme used in the radio system. The Applicants have
recognised that many radio systems use particular radio
modulation schemes which modulation schemes have
35   particular characteristics that can be assessed
relatively quickly. Thus considering the modulation of
the signal can give a good assessment of its

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suitability.

For example, in the TETRA system, π/4 DQPSK (π/4 Differential Quaternary Phase-Shift Keying) modulation is employed. This form of modulation has the particular
5   characteristic that there is a +/- π/4 or +/- 3π/4 radians phase shift between each transmitted symbol (there is never a phase shift of zero radians). The GSM system, on the other hand, uses GMSK (Gaussian Minimum Shift Keying) modulation, which employs phase shifts of
10 +/- π/2 radians relative to a steady RF (radio frequency) carrier. In this case a phase shift of zero is permitted, so a characteristic of GMSK modulation is the presence of phase shifts of either zero radians or π radians between successive symbols (more specifically
15 a +π is always followed by either 0 or -π, and no +π may follow +π and any subsequent 0's until a -π has occurred; a -π is always followed by either 0 or +π, and no -π may follow -π and any subsequent 0's until a +π has occurred). Other modulation schemes (such as 16QAM)
20 have other characteristics which can be detected in an appropriate manner. For example, a four-level FM modulation scheme will exhibit FM modulation with transitions between four different modulating frequencies, and so will show characteristic frequency
25 shifts.

Thus in a particularly preferred embodiment, the assessment of whether the signal on a particular frequency has the particular characteristic of the radio system comprises an assessment of whether the signal
30 exhibits the particular phase or frequency shift characteristics of the radio system's modulation scheme. This could be assessed by analysing the phase or frequency shifts between successive selected samples or portions, e.g. symbols, in the signal on the frequency
35 and comparing the observed phase or frequency shifts with the expected phase or frequency shifts for the wanted modulation scheme, e.g. to see how well they

correspond, to assess whether the signal carries the required form of modulation.

The analysis of the phase or frequency shifts can be carried out as desired and should be carried out at the same time as the signal level determination is carried out. Thus, in a TETRA system, for example, during the, say, 5 ms used to measure and average the signal level, the phase shifts between each successive symbol received during that period could be measured. Similarly where a frequency is assessed several times in the initial scan, by, e.g. measuring the signal level and modulation characteristics for a shorter time, e.g. 1 ms, and then changing frequency and repeating the cycle, e.g. 5 times and averaging the five measurements, the phase shifts between each successive symbol received during each scanning period could be measured. In the TETRA system, each symbol has a duration of 56 microseconds, so in the TETRA system up to 90 symbol phase shifts could be examined in the 5 ms period (or up to 18 in a 1 ms period).

The measured phase or frequency shifts can be used as desired to assess whether the signal has the particular characteristic. For example, the actual values of the phase shifts could be considered. The assessment could, for example, comprise looking at whether appropriate values and/or sequences of phase or frequency shifts are observed.

For example, if a TETRA signal was being sought, but random phase shifts are detected, then that would indicate a very poor TETRA signal. If phase shifts close to 0 or $\pi/2$ were prevalent, that would indicate a strong interfering signal using a different modulation scheme.

In another arrangement the measured phase shifts for the symbols could be mapped to a common (e.g. the first) quadrant (i.e. have their modulation induced phase differences removed) to obtain a mean phase shift

value and that value compared with the expected value
for the modulation scheme used by the radio system. The
variation in the values could also be considered.

In a particularly preferred embodiment, the
5   assessment of whether or not the scanned signal has the
particular characteristic comprises allocating a
probability that the signal has that characteristic
based on the assessment of the signal. Preferably three
levels of relative probability, low, medium and high,
10 are used. Thus preferably the fit of the candidate
signal to the desired characteristic is measured on a
probability scale and the probability of a match, e.g.
the probability that it carries the required form of
modulation, recorded. For example, the deviation of the
15 mean phase or frequency shift from the expected value if
the signal were to carry the correct form of modulation
and/or the proportion of measured phase or frequency
shift values having the value of the wanted modulation
scheme, could be used to classify how likely the signal
20 is to be from the correct radio system.

The reordering of the list of frequencies after the
initial faster scan has been completed can be carried
out as desired, based on the determined signal levels
and radio system characteristic assessments.

25 The Applicants have recognised that a valid but
weak signal will tend to exhibit a low to medium
probability of being valid for the radio system (since
weak signals will tend to suffer from much multipath
distortion and this will introduce errors into the
30 signal), but a higher signal level, valid signal, will
have a higher probability. On the other hand, a strong
signal showing a low probability of being valid can
reasonably be rejected.

Thus in a particularly preferred embodiment the
35 frequencies having signals having a high probability of
being valid (i.e. assessed to be likely to have the
particular characteristic) are considered first,

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preferably in signal level order (highest first), and so
on, with the signals having the lowest probability of
being valid being considered last. In such an
arrangement, the mobile radio unit will attempt to
5   synchronise to signals having a higher signal level and
a good assessment that they have the particular
characteristic first, and only after synchronisation to
those signals has failed will the mobile radio unit then
attempt to synchronise on signals assessed to have a
10   lower probability of being valid.

        The revised frequency order which is used for the
synchronisation scan can include all the frequencies in
the initial faster frequency scan list, but this is not
essential and it could include less frequencies. For
15   example, in a preferred embodiment, signals found to
have an undesirably low signal level are not included in
the synchronisation scan. This can be achieved by using
a threshold signal level to eliminate signals of
undesirably low signal level from the synchronisation
20   scan. Similarly, signals having less than a given
probability of having the correct radio system
characteristic could be eliminated from and not included
in the revised synchronisation scan frequency order
list.

25   The synchronisation scan should typically be
stopped once the mobile unit finds a suitable frequency
to synchronise to. If the mobile unit scans all the
frequencies in the revised frequency order list in turn
without finding a suitable signal, it could stop its
30   synchronisation scan then (and, for example, inform the
user accordingly), or, for example, repeat the scan
(for, e.g., up to a predetermined number of times)
before finally determining that synchronisation is not
possible.

35   In a particularly preferred embodiment of the
present invention, during the synchronisation scan when
the mobile radio unit is waiting for a synchronisation

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signal and attempting to synchronise to each frequency,
the mobile radio unit preferably also carries out an
assessment of whether the signal it is attempting to
synchronise to does have the particular characteristic
5   of the radio system, i.e. does belong to its radio
system, and interrupts and aborts its wait and
synchronisation attempt on that frequency, and switches
onto the next frequency in its list, if it determines
that the signal does not have the particular
10   characteristics (i.e. does not belong to its radio
system), e.g. it determines that there is greater than a
particular probability that the signal does not have the
particular characteristic. This allows the radio unit
to abort earlier a synchronisation attempt on an
15   unsuitable frequency. This arrangement may be
advantageous, because the pause on a given frequency
when attempting to synchronise is longer than the time
taken to assess each signal during the initial faster
frequency scan, and thus a more reliable signal
20   characteristic assessment may be able to be made, as,
e.g. the mobile radio unit will have longer to integrate
the phase shifts between symbols, than during the
initial faster frequency scan.
          It is believed that using an assessment of the
25   validity of a radio signal to abort a synchronisation
attempt is new and useful in its own right. Thus,
according to a third aspect of the present invention,
there is provided a method of synchronising a mobile
radio unit of a mobile radio communications system to a
30   radio channel of the system, the method comprising:
          the mobile radio unit scanning and attempting to
synchronise to each frequency on a stored list of
frequencies used by the radio system in turn;
          the mobile radio unit while it is waiting on a
35   particular frequency for synchronisation signals to
attempt to synchronise to the frequency, assessing
whether the signal on the frequency has a particular

characteristic of the radio system; and

the mobile radio unit aborting its wait on the
frequency and tuning to a new frequency before the
synchronisation attempt on the frequency is completed if
5 it determines that the signal on that frequency does not
have the particular characteristic.

According to a fourth aspect of the present
invention, there is provided a mobile radio unit of a
mobile radio communications system, the mobile radio
10 unit comprising:

means for scanning and attempting to synchronise to
each frequency on a stored list of frequencies used by
the radio system in turn;

means for, while the mobile radio unit is waiting
15 on a particular frequency for synchronisation signals to
attempt to synchronise to the frequency, assessing
whether the signal on the frequency has a particular
characteristic of the radio system; and

means for aborting its wait on the frequency and
20 tuning to a new frequency before the synchronisation
attempt on the frequency is completed if it determines
that the signal on that frequency does not have the
particular characteristic.

Again, the assessment of whether the radio signal
25 has a particular characteristic of the radio system is
preferably based on assessing whether or not it has a
characteristic of the radio modulation scheme used by
the radio system.

Although the present invention has been described
30 above with regard to the synchronisation scan operation
of a mobile radio unit seeking a radio channel, it is
believed that the idea of assessing whether a radio
signal on a given frequency has a particular
characteristic of a given radio system may be useful in
35 other circumstances as well. For example, in some non-
trunked radio systems a mobile radio unit may need to
establish that a radio frequency is available for use,

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i.e. that there is no signal from another radio unit of
the same radio system present on the frequency, before
it can seize the frequency for its use. For example, in
TETRA direct mode, a new transmitter is not permitted to
5   start using a radio channel (frequency) until it has
verified that there is not a TETRA signal already
present above some low signal level threshold, i.e. the
channel is "empty". Such assessment could be carried
out by assessing whether there is a signal on the
10   frequency having the characteristics, e.g. modulation,
of the particular radio system.

        Thus there may be situations where a mobile radio
unit needs to be able to confirm the absence of a
particular type of signal, and it is believed that the
15   technique of the present invention of assessing whether
the signal on a frequency has a particular
characteristic of a radio system could be used
advantageously for such verification.

        Thus, according to a fifth aspect of the present
20   invention, there is provided a method of operating a
mobile radio unit of a mobile radio communications
system, the method comprising the mobile radio unit:

        assessing whether the signal on a particular
frequency has a particular characteristic of the radio
25   system; and

        making a determination as to whether or not the
frequency already carries a signal of the radio system
based on the characteristic assessment for the
frequency.

30   According to a sixth aspect of the present
invention, there is provided a mobile radio unit for a
mobile radio communications system, the mobile radio
unit comprising:

        means for assessing whether the signal on a
35   particular frequency has a particular characteristic of
the radio system; and

        means for making a determination as to whether or

not the frequency already carries a signal of the radio
system based on the characteristic assessment for the
frequency.

In these aspects of the present invention, the
5   mobile radio unit preferably determines whether or not
to perform an action in relation to the particular radio
frequency, such as, for example, transmitting on the
frequency or attempting to synchronise on the frequency,
on the basis of the characteristic assessment for the
10   frequency.

These aspects of the present invention can include,
appropriately, any or all of the preferred and optional
features discussed above in relation to the other
aspects of the invention. Thus, the assessment of
15   whether the signal has the relevant particular
characteristic is preferably based on assessing whether
or not it has a characteristic of the radio modulation
scheme, such as particular frequency or phase shifts,
used by the radio system.
20   In this arrangement where appropriate, the mobile
radio unit could again search or scan through a list of
frequencies used by the system, and carry out an
assessment on each frequency, for example until such
time as it finds a free frequency for its use.
25   The methods in accordance with the present
invention may be implemented at least partially using
software e.g. computer programs. It will thus be seen
that when viewed from a further aspect the present
invention provides computer software specifically
30   adapted to carry out the methods hereinabove described
when installed on data processing means, and a computer
program element comprising computer software code
portions for performing the methods hereinabove
described when installed on data processing means. The
35   invention also extends to a computer software carrier
comprising such software which when used to operate a
mobile radio unit or a radio system comprising a digital

computer causes in conjunction with said computer said
radio unit or system to carry out the steps of the
method of the present invention. Such a computer
software carrier could be a physical storage medium such

5   as a ROM chip, CD ROM or disk, or could be a signal such
as an electronic signal over wires, an optical signal or
a radio signal such as to a satellite or the like.

It will further be appreciated that not all steps
of the method of the invention need be carried out by

10   computer software and thus from a further broad aspect
the present invention provides computer software and
such software installed on a computer software carrier
for carrying out at least one of the steps of the
methods set out hereinabove.

15   A number of preferred embodiments of the present
invention will now be described by way of example only.

The embodiments will be described with reference to
the TETRA system, although as will be appreciated from
the above, the invention is also applicable to other

20   mobile radio communications systems, such as the GSM
system.

An example of the operation of a mobile radio unit
in accordance with the present invention when it is
first switched on (i.e. of cold synchronisation) will

25   now be considered.

For this example, we will suppose that the mobile
radio unit stores a list of 60 frequencies where it can
expect to find system synchronization signals, and
requires 5 ms to tune its synthesizer to one of these

30   frequencies, and a further 5 ms to measure the signal
level on that frequency. We will further suppose that
considering the TETRA specification, base stations of
the radio system transmit synchronization bursts
(signals) at 1 second intervals on their particular

35   frequency, but that each synchronisation burst is in a
different one of the 4 TETRA timeslots, so that it takes
4 seconds for a synchronization burst to be repeated on

a particular timeslot.

When the mobile radio unit has just been switched
on, its first task is to locate a TETRA radio system as
quickly as possible. In the basic prior art system
5   discussed above, the mobile unit would tune to each
frequency in its stored list in turn and monitor each
frequency for a minimum of 1 second, to be sure of
listening at the time a base station would be
transmitting a synchronization burst. The search time
10   for the 60 frequencies will be of the order of 1 minute
(but there is a 1 in 1080 chance that the search time
will be only 15 ms and a 1 in 60 chance that the search
time will be 1 second).

Now consider a more sophisticated mobile radio
15   unit, operating the prior art technique of initially
scanning all 60 channels in its list to build up a table
of signal levels before attempting synchronisation. A
fast scan duration of 5 seconds (which is a typical time
selected for such a frequency scan, being a reasonable
20   compromise between the need to sample signals over as
great a distance as possible to help ensure sample
de-correlation and the desire not to "waste" too much
time doing the scan) will be assumed. At 5 ms tuning
time and 5 ms signal level measurement time, this fast
25   scan duration will give 8 spaced signal samples per
frequency, which is a reasonable number. Having ordered
the frequencies in order of signal level the mobile
radio unit then returns to each frequency in the revised
order to attempt synchronisation on that frequency. In
30   the absence of interfering signals it should be able to
synchronize after a further 1 second. Thus in this case
the maximum time to synchronize should be 6 seconds (5
seconds to scan plus 1 second to synchronise), but there
is a 1 in 18 chance of synchronizing in 5.015 seconds.
35   It would not be possible to synchronize from cold faster
than this.

However, as discussed previously, interfering

signals will reduce the benefits of this method of
searching. The interference could be accidental (e.g.
vehicle ignition pulses or a nearby desktop or laptop
computer), or it could be intentional transmissions from
another system using a different modulation scheme. The
latter is a potential problem for TETRA systems, which
share frequencies with military users.

     In the case where the two strongest signals turn
out to be interference, the mobile radio unit in this
example would still attempt to synchronise to those
unsuitable signals first, thereby introducing a further
delay of 8 seconds (it taking 4 seconds to reject each
interference frequency). In this case the cold
synchronization time would be at least 13.015 seconds (5
seconds to scan, 8 seconds to reject the two
interference frequencies and 0.015 seconds to
synchronise to the third frequency tested), but more
probably 14 seconds.

     Now consider a mobile radio unit which employs the
method of the present invention. It first performs a
fast frequency scan in which it dwells on each frequency
(at several spaced intervals) for 5 ms to record the
average signal level, and at the same time records the
digital samples received by its demodulator and using a
digital signal processor, examines the recorded digital
samples, looking for evidence of $\pi/4$ and $3\pi/4$, but never
zero, phase shifts at the expected symbol rate. The
probability that this has been detected is stored with
the averaged signal level. (This can be done while the
mobile radio unit is tuning to the next frequency in the
list.) This fast frequency scan would again, as
discussed above, typically be arranged to be carried out
over a period of the order of 5 seconds to try to ensure
sufficient spaced samples for each frequency. After
this initial "fast" frequency scan, the scanned
frequencies are then ordered according to their averaged
signal levels and the probability that their signal has

the required particular modulation characteristics, to
provide a revised scanning order list of the frequencies
in the list.

    In this case, if the two strongest signals are
again interference, those frequencies will have strong
signal levels, but low probabilities of having the
particular modulation characteristic. Thus when the
mobile radio unit has completed its fast scan, it will
place those two strongest signals low in its revised
frequency scanning order as they are recorded as having
a low probability of bearing TETRA modulation. Instead,
the mobile radio unit will tune straight to the third
strongest signal, which, for example, has been recorded
as having a medium or high probability of carrying TETRA
modulation. Thus the mobile unit's cold synchronization
delay would remain in the region of 5.015 to 6 seconds
(i.e. 5 seconds to scan and 1 second to synchronise).

    We will now consider what happens when a mobile
radio unit needs to identify a new base station for
handover, i.e. while it is engaged in a call.

    In the first, basic prior art technique, discussed
above, the mobile radio unit has to listen for each
potential new base station in turn. The base stations'
TDMA frame structures in TETRA are not synchronized, so
in order to find a synchronization burst on an adjacent
cell, the mobile station retunes its synthesizer between
reception slots. This allows it to look for
approximately two time slots for a possible
synchronization burst on an adjacent cell before having
to retune back to the serving cell frequency, and this
can be done in each frame.

    As the synchronization bursts cycle through the
time slots the mobile radio unit will have to wait up to
4 seconds to ensure that a synchronization opportunity
has occurred, before choosing a new frequency. At this
rate, the mobile radio unit could take up to 4 minutes
to synchronize to a new base station, by which time the

call would most probably have been lost, even if the
frequencies of the six adjacent cells had been broadcast
to allow a reduced frequency list to be searched.

5   The more sophisticated prior art mobile radio unit
of the previous example could attempt to keep its table
of signal strengths always up to date. It might even
attempt to store synchronization data on the best
alternative base station, so that handover can be
achieved without any searching delays. However, suppose
10   that for some reason the signal strength table needs to
be renewed (as could happen if the mobile radio unit has
rounded a bend in a high-sided valley, or entered a new
street in a high rise urban environment). As before,
the mobile radio unit performs its fast scan of signal
15   levels in 5 s, and then searches each entry in the list
in sequence. Considering again the case where the two
strongest signals are in fact interference, the mobile
radio unit would have to pause on the unsuitable first 2
frequencies for at least 4 seconds each as before (or 8
20   seconds each, if giving the receiver 'two bites at the
cherry' as is usual, to reduce the effects of fading).
After pausing a further 4 (or 8) seconds on the third
frequency in the list, it achieves synchronization,
after a delay of between 13 and 17 seconds (or 21 and 29
25   seconds in a faded channel). The call might have been
lost during this interval.

        If the mobile radio unit employs the method of the
present invention, it will in this case rank the two
strongest signals quite low, as shown in the previous
30   example, and attempt to synchronize to the third
strongest signal (i.e. the strongest signal showing a
high probability of having the right modulation scheme).
The synchronization delay is now reduced to between 5
and 9 seconds (or 13 seconds in a faded channel).

35   It can be seen from the above that the mobile radio
unit operating in accordance with the present invention
uses both the signal level and radio system

characteristics derived during the initial faster
frequency scan when deciding which frequencies to
attempt to synchronise to. It in effect supplements the
signal level information determined during the initial

5   faster frequency scan with data indicating the
probability that the corresponding signal is useful.
This improves the ranking of the signals to then attempt
to synchronise to, and thus reduces the probability of
wasting time trying to synchronise on incompatible

10   signals.

Claims

1.   A method of operating a mobile radio unit of a
mobile radio communications system, in which radio
5   system the mobile radio unit stores a list of target
frequencies to scan for a suitable frequency for
communicating with a base station of the radio system,
the method comprising:
        the mobile radio unit scanning each frequency in
10   its list, and determining for each frequency the signal
level of the signal on that frequency, and assessing for
each frequency whether the signal on that frequency has
a particular characteristic of the radio system;
        the mobile radio unit then determining a revised
15   frequency order on the basis of the determined signal
levels and the characteristic assessments for each
frequency; and
        the mobile radio unit then attempting to
synchronise to the frequencies in the revised frequency
20   order in the order of the revised frequency order.

2.   The method of claim 1, wherein the initial scan of
each frequency in the list comprises the mobile unit
taking signal samples at spaced intervals on each
25   frequency.

3.   The method of claim 1 or 2, wherein the signal
characteristic assessment comprises assessing whether
the signal has a characteristic of the radio modulation
30   scheme used in the radio system.

4.   The method of claim 3, wherein the signal
characteristic assessment comprises assessing whether
the signal exhibits particular phase or frequency shift
35   characteristics of the radio system's modulation scheme.

5.   The method of claim 4, wherein the step of

assessing whether the signal exhibits particular phase
or frequency shift characteristics of the radio system's
modulation scheme comprises analysing the phase or
frequency shifts between successive selected samples or
5   portions in the signal on the frequency and comparing
the observed phase or frequency shifts with the expected
phase or frequency shifts for the wanted modulation
scheme.

10   6.   The method of claim 4 or 5, comprising using the
deviation of the mean observed phase or frequency shift
for the signal being assessed from the expected value if
the signal were to carry the correct form of modulation
and/or using the proportion of observed phase or
15   frequency shift values having the value of the wanted
modulation scheme, to classify how likely the signal is
to be from the correct radio system.

7.   The method of any one of the preceding claims,
20   wherein the assessment of whether or not the scanned
signal has the particular characteristic comprises
allocating a probability that the signal has that
characteristic based on the assessment of the signal.

25   8.   The method of any one of the preceding claims,
wherein the revised frequency order is determined such
that frequencies having signals assessed to be most
likely to have the particular characteristic are
attempted to be synchronised to first, and the signals
30   assessed to be least likely to have the particular
characteristic are attempted to be synchronised to
last.

9.   The method of claim 8, wherein the revised
35   frequency order is further arranged in signal level
order.

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10. The method of any one of the preceding claims,
further comprising eliminating signals having a signal
level less than a threshold signal level from the
revised frequency order.

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11. The method of any one of the preceding claims,
comprising: the mobile radio unit, during the
synchronisation scan when the mobile radio unit is
attempting to synchronise to each frequency and is
10   waiting for a synchronisation signal, carrying out an
assessment of whether the signal it is attempting to
synchronise to does have the particular characteristic
of the radio system, and interrupting and aborting its
wait and synchronisation attempt on that frequency, and
15   switching onto the next frequency in the list, if it
determines that the signal does not have the particular
characteristic.

12. A method of synchronising a mobile radio unit of a
20   mobile radio communications system to a radio channel of
the system, the method comprising:
        the mobile radio unit scanning and attempting to
synchronise to each frequency on a stored list of
frequencies used by the radio system in turn;
25   the mobile radio unit while it is waiting on a
particular frequency for synchronisation signals to
attempt to synchronise to the frequency, assessing
whether the signal on the frequency has a particular
characteristic of the radio system; and
30   the mobile radio unit aborting its wait on the
particular frequency and tuning to a new frequency
before the synchronisation attempt on the particular
frequency is completed if it determines that the signal
on the particular frequency does not have the particular
35   characteristic.

13.   A method of operating a mobile radio unit of a
mobile radio communications system, the method
comprising the mobile radio unit:

      assessing whether the signal on a particular
5   frequency has a particular characteristic of the radio
system; and

      making a determination as to whether or not the
frequency already carries a signal of the radio system
based on the characteristic assessment for the
10   frequency.

14.   A mobile radio unit for use in a mobile radio
communications system, in which system plural
frequencies are used for radio communications, the
15   mobile radio unit comprising:

      means for storing a list of frequencies used by the
radio system;

      means for scanning each frequency in the stored
list;

20   means for determining for each scanned frequency
the signal level of the signal on that frequency;

      means for assessing for each scanned frequency
whether the signal on that frequency has a particular
characteristic of the radio system;

25   means for determining a revised frequency order
based on the determined signal levels of each frequency
and the assessments of whether each frequency has the
particular characteristic of the radio system; and

      means for attempting to synchronise to the
30   frequencies in the revised frequency order in the order
of the revised frequency order.

15.   The mobile unit of claim 14, wherein the signal
characteristic assessment means comprises means for
35   assessing whether the signal has a characteristic of the
radio modulation scheme used in the radio system.

16. The mobile unit of claim 15, wherein the signal characteristic assessment means comprises means for assessing whether the signal exhibits particular phase or frequency shift characteristics of the radio system's modulation scheme.

17. The mobile unit of claim 16, comprising means for classifying how likely the signal is to be from the correct radio system on the basis of the deviation of the mean observed phase or frequency shift for the signal being assessed from the expected value if the signal were to carry the correct form of modulation and/or on the basis of the proportion of measured phase or frequency shift values having the value of the wanted modulation scheme.

18. The mobile unit of any one of claims 14 to 17, wherein the revised frequency order determining means is arranged to determine the revised frequency order such that frequencies having signals assessed to be most likely to have the particular characteristic are attempted to be synchronised to first, and signals assessed to be least likely to have the particular characteristic are attempted to be synchronised to last.

19. The mobile unit of claim 18, wherein the revised frequency order determining means is further arranged to determine the revised frequency order in signal level order.

20. The mobile unit of any one of claims 14 to 19, wherein the revised frequency order determining means is arranged to eliminate signals having a signal level less than a threshold signal level from the revised frequency order.

21. The mobile unit of any one of claims 14 to 20,

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comprising

    means for, during the synchronisation scan when the
mobile radio unit is attempting to synchronise to each
frequency, while the mobile unit is waiting for
5   synchronisation signals, assessing whether the signal it
is attempting to synchronise to does have the particular
characteristic of the radio system; and
    means for interrupting and aborting the wait and
synchronisation attempt on that frequency, and for
10   switching onto the next frequency in the list, if it is
determined that the signal does not have the particular
characteristic.

22. A mobile radio unit of a mobile radio
15   communications system, the mobile radio unit comprising:
    means for scanning and attempting to synchronise to
each frequency on a stored list of frequencies used by
the radio system in turn;
    means for, while the mobile radio unit is waiting
20   on a particular frequency for synchronisation signals to
attempt to synchronise to the frequency, assessing
whether the signal on the frequency has a particular
characteristic of the radio system; and
    means for aborting the wait on the particular
25   frequency and tuning to a new frequency before the
synchronisation attempt on the particular frequency is
completed if it is determined that the signal on the
particular frequency does not have the particular
characteristic.
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23. A mobile radio unit for a mobile radio
communications system, the mobile radio unit comprising:
    means for assessing whether the signal on a
particular frequency has a particular characteristic of
35   the radio system; and
    means for making a determination as to whether or
not the frequency already carries a signal of the radio

system based on the characteristic assessment for the
frequency.

24.   A computer program element comprising computer
software code portions for performing the method of any
one of claims 1 to 13 when installed on data processing
means.

25.   A method of operating a mobile radio unit of a
mobile radio communications system substantially as
hereinbefore described.

26.   A mobile radio unit for use in a mobile radio
communications system substantially as hereinbefore
described.

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04Q7/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 522 885 A (NIPPON ELECTRIC CO) 13 January 1993 (1993-01-13) the whole document	1-26
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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
28 February 2001	07/03/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roberti, V

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04L12/28   H04Q7/32   G06K17/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   H04L H04Q G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category°	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☐ Further documents are listed in the continuation of box C.	☒ Patent family members are listed in annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 February 2005	01/03/2005

Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Authorized officer LOPEZ PEREZ M C

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